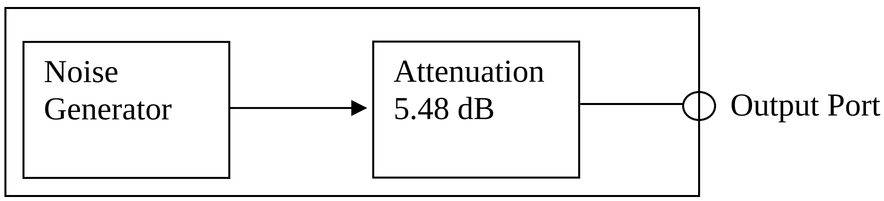
Converting Between Temperature and dBm and dBm and Temperature

R.S.Flagg April 2019

Consider a wideband noise generator connected thru an attenuator and a power divider to an output port.



The insertion loss between the generator and the output port has been measured using a VNA to be 5.48 dB

The loss of 5.48 dB equates to a loss ratio of **[10^(5.48/10) = 3.53]** so in order to have a temperature of 100 MK at the output port the output temperature from the noise generator itself must be **[3.53*100 MK = 353 MK].**

The output temperature of the noise generator is determined by using a spectrum analyzer to measure the power in a known analysis bandwidth. For this example the analyzer bandwidth (B) will be set to 10 kHz. (This is equivalent to the IF bandwidth of a receiver. There is nothing particularly sacred in this choice of bandwidth – but it seems to work well).

Temperature and power are related by a simple equation **P=kTB (or T=P/kB**) 1.

P is power in watts, k is Boltzmann's constant (1.38E-23), T is temperature in kelvins, and B is bandwidth in Hz

The spectrum analyzer displays power in dBm (decibels below 1 milliwatt), not in watts, so we have to do a bit of manipulating instead of using equation 1 directly.

We can determine the output temperature of the noise generator itself, or the temperature at the output port, depending on where we connect the spectrum analyzer. For this example let's determine what the spectrum analyzer should measure in dBm if the noise source temp is 353 MK and the analyzer bandwidth is set to 10 kHz.

Using P=kTB = (1.38E-23)*(353E6)*(1E4) = 4.87E-11 watts.

Since there are 1000 milliwatts in 1 watt the power in milliwatts (mw) is 1000*(4.87E-11) = 4.87E-8 mw).

Expressed in dBm using **10*LOG(P in mw) =10*LOG(4.87E-8)**, the measured power from the 353 MK source should be **-73.12 dBm**.

Now let's work the problem backwards and assume we have measured the noise generator output power in dBm, and compute the noise generator temperature.

The first step is to convert the dBm value into milliwatts (mw).

P in mw = **10^(dBm/10)** = 10^(-73.12/10) = 4.87E-8 mw

Next convert mw into watts: P in watts = .001*(4.87E-8) = 4.87E-11 watts

And finally determine the temperature using: T=P/kB

T= (4.87E-11)/((1.38E-23)*(1E4)) = (4.87E-11)/(1.38E-19) = 353MK

Averaging readings in dBm

When making dBm measurements with the spectrum analyzer it is often helpful to average several readings together to reduce the differences in readings due to their noisy nature. Unfortunately readings in dBm should not be averaged together. Instead the readings should first be converted to power – averaged, and then converted back into dBm. The following example illustrates the difference in averaging methods

Method 1 – averaging in dBm
Consider 3 readings in dBm. -80, -75 and -70. If we take the average in dBm we get -75.

Method 2 - Converting first to power and taking the average and converting back into dBm we get the proper answer.

10^(-80/10) + 10^(-75/10) + 10^(-70/10) = (1E-8) + (3.2E-8) +(1E-7) =1.42E-7

And averaging = (1.42E-7)/3 = 4.7E-8

Converting back to dBm =10 *Log (4.7E-8) = **-73.248 dBm**